An Empirical Study of Employees' Safety Perceptions of Site Hazard/Accident Scenes

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Abstract

Despite the improvement of digital technologies (e.g., building information modeling) in enhancing construction safety management, human factor-related issues such as individual perceptions, attitudes, and behavior in safety cannot be downplayed. Existing studies have addressed safety issues by assessing site hazards and preventing avoidable accidents. Such approaches to safety management can be undertaken through the establishment of safety climates and safety cultures, as well as identifying certain demographic or subgroup factors that affect safety management. Aiming to expand the subgroup factor analysis in safety management and integrate it with hazard/accident categorization, this study adopted a site survey approach by recruiting construction employees from multiple job duties and trades. The follow-up statistical analysis revealed that: 1) a hazard/accident scene with higher occurrence and lower severity caused a higher variation among employees' opinions in perceiving its severity; 2) entry-level employees were likely to be more cautious about hazards but their cautiousness might diminish as they gained more site experience; 3) compared to early career employees and senior peers, the mid-career professionals tended to underestimate severities of a given hazard/accident scene. This study categorized eight commonly encountered site hazard/accident scenes, integrated them in the analysis of

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subgroup differences based on employees' job duties or work trades, and their experience levels. Future research was also recommended addressing individuals' safety perceptions and demographic factors in safety management.

Keywords: Construction safety; accident category; safety hazards; individual perception; work trades; human factors; subgroup analysis

Introduction

Occurrence of occupational accidents is one major issue in the construction industry (Yılmaz and Kanıt, 2018). Aiming to prevent site accidents and mitigating risks caused by hazards, research in construction safety has been highly focused on exploring effective safety management programs (see Chen and Jin, 2012), building the framework and models of safety climate and culture (e.g., Choudhry et al., 2009; Li et al., 2017), as well as predicting and enhancing safety performance (Fang et al., 2015; Xia et al., 2018). Besides these key research areas in construction safety, digital technologies in safety management has gained more application in recent years, such as the studies of de Melo et al. (2017), Zou et al. (2017), and Dong et al. (2018). A review of these research focuses within construction safety inferred that despite of the assistance of emerging technologies (e.g., building information modeling) in safety management (Martínez-Aires et al., 2018), human factors still play the key role, as safety performance is highly related to safety culture and safety climate (Choudhry et al., 2009; Molenaar et al., 2009; Li et al., 2017), which is reflected by individuals' perceptions of safety hazards and risks (Chen and Jin, 2015). Also, psychological effects have a significant impact on employees' safety behaviors, and further affecting the overall safety performance (Wang et al., 2018).

Human factors in construction safety include demographic factors, or subgroup variations, which cannot be ignored in safety management. For example, migration workers face language barriers and communication difficulties (Hare et al., 2013). Besides, other subgroup factors should also be considered when implementing safety training, education, or programs, because perceptions towards risks or hazards are subjective and are affected by multiple individual factors (e.g., culture) according to Slovic (1992). These individual factors in construction safety climate include employees' job position, duties, and work trades. It has been identified by existing studies (e.g., Hinze et al., 2013) that safety practices need the commitment crossing job duties or positions, including workers, management personnel, the owner, etc. Therefore, the subgroup issues in construction safety are continually being studied because achieving a safe work environment requires joint effort from site professionals involved in different roles, positions and duties.

Gaps in existing research of demographic factors within safety management are identified in that: 1) not many studies in safety hazards, accidents, or risks have incorporated the nature of these hazards or accidents based on their occurrence, severity, and easiness of being noticed on-site; 2) insufficient research has been performed to investigate how the nature of these safety hazards/accidents would affect individuals' safety perceptions; and 3) there have been limited studies conducted in exploring more subgroup issues (e.g., trades and experience levels) in safety perceptions of hazard/accident scenes. Adopting a site questionnaire survey-based approach followed by statistical analysis, this study aimed to: 1) categorize eight commonly encountered safety hazards/accidents according to historical safety data and pilot site investigation; 2) develop a valid site survey approach incorporating psychometric paradigm (Slovic, 1992) and image-based scenes representing these hazards/accidents; 3) evaluate the overall perception of site employees towards the eight hazard/accident scenes; 4) conduct subgroup analysis of employees' perceptions according to whether or not they were in a management position; and 5) perform further subgroup analysis by dividing employees based on their job duties/trades, as well as their experience levels. This research contributes to the existing studies within human factors in construction safety by integrating the nature of hazards and accidents. Particularly, how the nature of the hazards/accidents affect individual perceptions is studied. The study also provides insights into both researchers and practitioners in construction safety in terms of how individual employees' perceptions would be affected by their job duties or work trades, as well as their site experience. The current study leads to further research on tracking employees' safety perception and attitude changes following their career path, and the exploration of effective safety management which addresses individual differences in terms of career stages and trades.

Literature review

Safety hazard/accidents

The Occupational Safety and Health Administration (OSHA, 2011) defined Focus Four Hazards, namely falls, electrocution, struck-by, and caught-in or -between. Among them, temporary work at height (e.g., working with scaffolding) is one of the primary causes of construction accidents leading to injuries and even fatalities (Rubio-Romero et al., 2013). Besides post-accident data analysis (e.g., Zhou et al., 2012; Kim et al., 2013), multiple studies (including Goh and Chua, 2009; Goh and Chua, 2010; Hallowell and Gambatese, 2010; Mitropoulos et al., 2010; Mitropoulos and Namboodiri, 2011; Fortunato, et al., 2012; Gangolells, et al., 2013) have focused on identifying, measuring, and assessing site hazards/risks as well as preventing corresponding accidents. To minimize risks associated with these hazards and accidents, it has been suggested in multiple studies (e.g., Hallowell and Gambatese, 2009; Zou and Zhang, 2009; Chen and Jin, 2012; Esmaeili and Hallowell, 2012) that safety education, training, or formal safety program should be enforced to all site participants, including the management personnel (Sunindijo and Zou. 2012; Sunindijo and Zou. 2013) and workers (Chen and Jin, 2013).

Interrelations among safety perception, safety climate, and safety culture

Workplace safety perception was identified by Chen and Jin (2013), together with safety awareness and attitudes, as well as management involvement (Li et al., 2017) to form part of safety climate. According to Cox and Flin (1998) and NORA (2008), safety climate focuses on workers' perception of the role of safety in the workplace and their attitudes towards safety. Safety culture is a top-down organizational attribute approach that addresses safety management (Mohammed, 2003). Safety culture could be described by safety commitment, safety incentives for safe performance, safety accountability and dedication, as well as disincentives for unsafe behaviors (Molenaar et al., 2009). Safety climate reflects the safety culture (Mearns et al., 2003), and thus can measure safety culture (Chen and Jin, 2013), which directly affects safety performance (Choudhry et al., 2009; Molenaar et al., 2009). Both safety culture and safety climate are multi-level based on whether or not employees hold a management position (Grote and Kunzler, 2000; Chen and Jin, 2012), and even different levels in management (NORA, 2008). Workers and supervisors form different subgroup safety climates (Melia et al., 2008). Construction employees' from different positions, through their own subgroup safety climate, might have varied safety perceptions as indicated by Chen and Jin (2015).

Demographic and subgroup factors in construction safety perceptions

Safety climate and safety culture could be divided according to subgroup categories (Schein, 1996) and they can be measured by employees' safety perceptions (Zohar, 1980; Brown and Homes, 1986; Dedobbeleer and Béland, 1991; Chen and Jin, 2015). Certain demographic factors in their effects in workers' perceptions towards construction site hazards or risks have been studied. For example, del Puerto et al. (2013) found that Latino workers in the U.S. construction industry were more likely to believe that productivity and quality were more important than safety. Latino workers tended to underestimate site dangers, and they had a higher rates of injuries and fatalities (del Puerto et al., 2013). Other demographic factors such as workers' age, and other subgroup factors (e.g., workers from general contractor or subcontractor and from different trades) were studied by Chen and Jin (2015), and was concluded that older workers tended to have a better safety attitude and overall perceptions than their younger peers. Subcontractor involvement was also considered by Molenaar et al. (2009) as part of the safety culture that affected safety performance.

Methodology

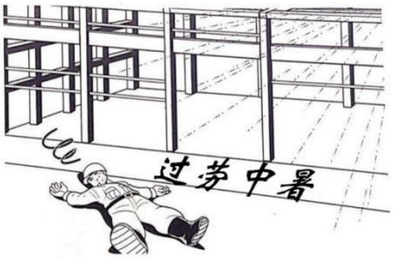
The methodology adopted in this study consisted of jobsite survey and follow-up statistical analysis.

Construction site survey

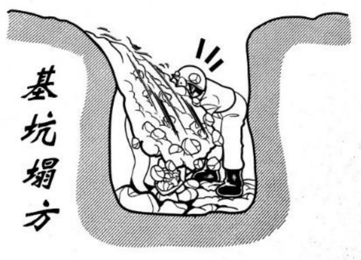
The psychometric paradigm was adopted in this study. According to Slovic (1992), the psychometric paradigm encompasses the theory that risks are subjectively defined by individuals who may be influenced by a wide array of psychological, social, institutional and cultural factors. The paradigm assumes that, with appropriate survey instruments, these factors and their interrelationships can be quantified and modeled to illuminate the individuals’ responses confronting them (Slovic, 2012). The psychometric paradigm has been the most influential model in the field of risk, and the “cognitive maps” of hazards produced by the paradigm could explain how the various risks were perceived (Siegrist et al. 2005). In this study, risks displayed by eight different scene images were incorporated in the questionnaire-based site survey. Individuals working on construction sites were studied for their perceptions towards the eight safety hazard/accident scenes on-site. Fig.1. displays these eight images.

a) Hazard 1 (H1): Loss of body balance and falling from working at height

b) Hazard 2 (H2): Failure of temporary working platform

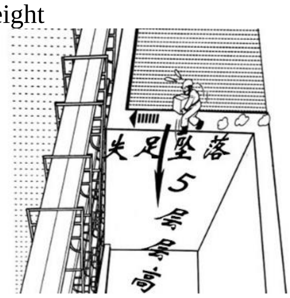


c) Hazard 3 (H3): Falling from uncovered holes



d) Hazard 4 (H4): Falling from scaffolding when working at height

e) Hazard 5 (H5): Sunburn and heat exhaustion due to over-exposure to high temperature



f) Hazard 6 (H6): Falling from unstable ladder

g) Hazard 7 (H7): Collapse of foundation pits

h) Hazard 8 (H8): Hands hurt by an object

Fig.1. Eight site hazard/accident scenes in the questionnaire survey (scenes of safety hazards/accidents adopted from Zhang, 2009)

These eight safety hazard/accident scenes (i.e., from H1 to H8) illustrated in Fig.1 were prepared according to three different risk categories related to their occurrence (i.e., frequent to occasional), severity (i.e., highly dangerous to less dangerous), and visibility (i.e., easily noticed to not obvious on-site).

A pilot study on local jobsites from Jiangsu China was conducted during April and May of 2016. Scenes representing different safety hazards/accidents were shown to site employees in the pilot study. Their feedback was collected to ensure that these image-based scenes with Chinese text descriptions were reasonable and valid to study employees' perceptions of safety. The formal site visit and questionnaire survey was conducted in eastern China (specifically, Shanghai and Jiangsu regions) from May to August in 2016. Site personnel were asked to rank all the eight scenes displayed in Fig.1 using Likert-scale scores, with *1* being "not dangerous at all regarding the given safety hazard", *2* meaning "not really dangerous", *3* indicating a neutral attitude, *4* inferring "quite dangerous", and *5* referring to "very dangerous". The survey participants on jobsites were asked of their job roles or trades, and experience level measured by years of working in the construction industry. As first impressions are critical to judgements of threats and last long into a relationship (Holmes, 2016), survey participants in this study were also guided to select the Likert-scale option based on their first impression of the given scene rather than consciously evaluating it.

Statistical analysis

Besides the basic statistical values including mean and standard deviation used to measure the perceptions of the overall survey population, Cronbach's Alpha analysis (Cronbach, 1951; Tavakol and Dennick, 2011) was also implemented to test the internal consistency of the survey population's perceptions of the eight scenes. Ranging from *0* to *1*, a high Cronbach's Alpha value indicates a higher degree of consistency of site individuals' perceptions among the eight scenes. Nunnally and Bernstein (1994), Bland and Altman (1997), and DeVellis (2003) stated that an Alpha value between *0.70* and *0.95* would suggest a fairly high internal inter-relatedness among Likert-scale items. A higher Conbach's Alpha value in this eight scenes-based survey would infer that a site employee who chooses a Likert-scale score to one safety hazard/accident scene is more likely to select a similar numerical option to other scenes.

The whole sample was then divided into subgroups according to different demographic factors, including job position, duties or work trades, and experience levels. The survey population was initially categorized into management personnel and workers. The two main categories were then further divided into more subgroups according to their management duties (i.e., safety or non-safety-specialized management) and work trades (e.g., electricity, carpentry, and plumbing, etc.). The whole sample could also be divided into subgroups with different experience levels according to their years of working in the construction industry. Several statistical methods were applied in the subgroup analysis, including the two-sample *t*-test and one-way Analysis of Variance (ANOVA), both of which are parametric methods.

Parametric methods (e.g., ANOVA) have been adopted in previous studies in the field of construction engineering and management (e.g., Aksorn and Hadikusumo, 2008; Meliá et al., 2008; Tam, 2009; Jin et al., 2017), specifically for Likert-scale items.

Existing studies such as Carifio and Perla (2008) and Norman (2010) have proved the robustness of applying parametric methods in survey samples that were either small-sized or not normally distributed. Examples of small sample sizes such as a sub-sample size at *four* in the study of Tam (2009) as well as highly skewed subsample sized of *four* in Pearson (1931) can be found in parametric method-involved research. In comparison, the overall sample size at *155* and subgroup sizes in this construction safety study were considered adequate.

The two-sample *t*-test was applied in this study to evaluate the mean values between management personnel and workers for each Likert-scale item as well as the average perception of the eight safety scenes. Based on the null hypothesis that management personnel and workers had consistent perceptions towards the given safety hazard/accident scene, a *t* value and the corresponding *p* value would be computed to test the hypothesis. Setting the level of significance at *5%*, a *p* value lower than *0.05* would reject the null hypothesis and suggest that there is a significant difference between management personnel and workers in their perceptions. Similar to the two-sample *t*-test, ANOVA also aimed to test whether subgroups had similar perceptions towards the given safety hazard/accident scene. Based on the similar null hypothesis and the same level of significance, a *F* value and the corresponding *p* value were computed to test the null hypothesis. A *p* value lower than *0.05* indicates that there are different views among subgroups categorized by job duties/trades or experience levels towards the safety hazard/accident scene.

Results and findings

Following the safety accidents reported from 2014 to 2017 in China, safety data in terms of number of accidents, fatalities, severe injuries, percentages accounting for total accidents, and severity measurement are summarized in Table 1.

Table 1. Safety data analysis (data summarized according to accident reports from Division of Safety Supervision, 2017)

Type of accidents	Number of accidents	Fatality	Severe injuries	Percentage	Severity (fatality or severe injury rate per accident)
Falling from working at height	1013	1081	37	53%	1.1
Structural collapse	237	454	90	12%	2.3
Struck-by	277	289	8	15%	1.07
Electrocution	48	50	0	3%	1.04
Injuries by manual handling or lifting	166	245	34	9%	1.68
Injuries by heavy equipment	109	120	17	6%	1.26
Hit by site vehicles	27	30	0	1%	1.11
Suffocation, choking, and poising	20	37	3	1%	2
Total	1897			100%	

The eight scenes presented in Fig.1 can be tagged using different combinations of hazard/accident categories according to either Table 1, or the site collected from the pilot study. Table 1 provides the statistical evaluation of occurrence and severity of a certain accidents. For example, falling from working at height is a frequent accident; accidents caused by structural collapse (e.g., pit collapse) is highly dangerous due to its high fatality or severe injury rate per accident; struck-by an object may be considered an accident type with lower severity. The visibility of an accident can be determined by feedback collected from the pilot study. For example, H5 shown in Fig.1 is considered as a hazard that is not easily detected due to the suddenness of the working platform failure. In comparison, H7 is perceived a hazard that can be easily noticed. Table 2 lists the combination of categories assigned to each of the eight scenes.

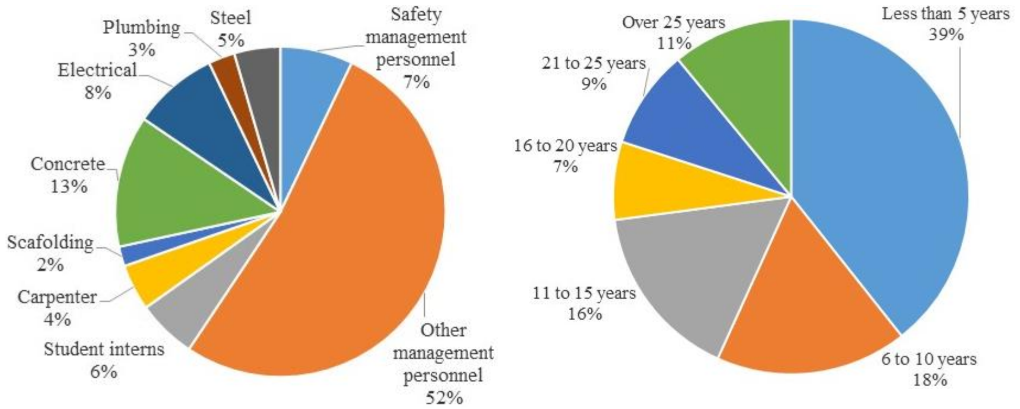
Table 2. The combination of categorization of eight safety hazard/accident scenes on-site

Category	H1	H2	H3	H4	H5	H6	H7	H8
Occurrence	Lower frequency	High frequen-cy	High freque-ncy	Lower frequenc-y	Lower frequenc-y	High frequen-cy	Lower frequen-cy	High freque-ncy
Severity	High severity	High severity	Low severity	High severity	Low severity	High severity	Low severity	Low severity
Visibility	Easily noticed	Not easily noticed	Not easily noticed	Not easily noticed	Not easily noticed	Easily noticed	Easily noticed	Easily noticed

Following the definition of these eight site hazard/accident scenes shown in Fig.1 and categorizations described in Table 2, the following sections will present the findings from the site questionnaire survey in terms of the background information of the survey sample, overall sample analysis in perceptions, analysis of sub-samples divided into management personnel and workers, subgroup analysis of survey participants among different trades or job duties, and the sub-sample analysis according to their experience levels.

Background information of the survey sample

A total of *155* valid responses from *176* questionnaires received from jobsite survey were used in the sample data analysis. Among the *155* responses, *95* of them were management staff specializing in safety or other management positions (e.g., crew foremen), and the rest *60* participants were site workers. The percentages of respondents crossing different positions and trades are shown in Fig.2. Also displayed in Fig.2 is the distribution of respondents falling into different categories of experience levels based on their years of working on-site.



a) Percentages of survey participants from different positions or trades

b) Percentages of respondents from different experience levels

Fig.2. Background information of survey respondents

It can be seen from Fig.2 that demographically, the whole survey sample can be divided into nine different categories in terms of their job duties (safety management or other types of management) or work trades (e.g., scaffolding). Six different subgroups could be identified according to years of experience in the construction industry.

Overall sample analysis

The average and standard deviation of survey respondents' perceptions towards the eight scenes were compared and summarized in Fig.3.

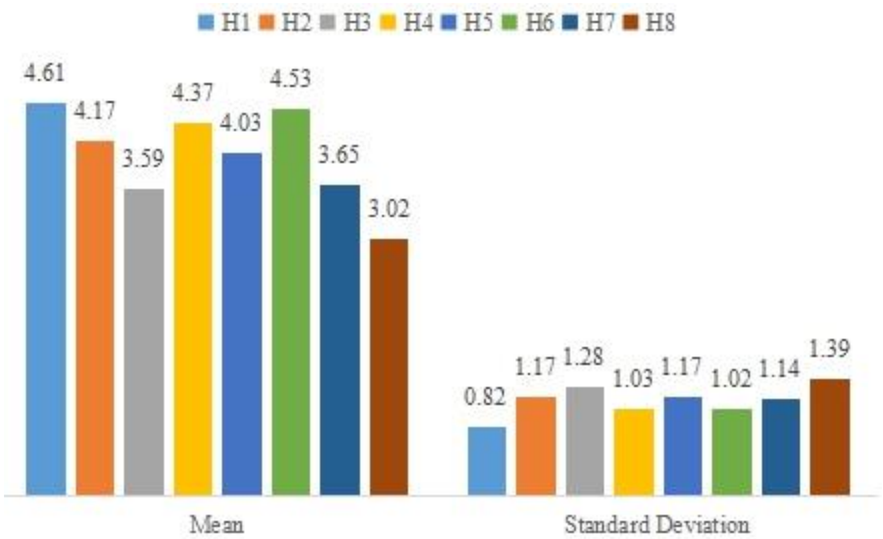


Fig.3. Basic statistics of the overall survey sample's perceptions toward the given safety hazard

According to Fig.3, H1 (i.e., occasional, easily noticed, and highly severe scene) was perceived most dangerous, followed by H6 (i.e., frequent, easily noticed, and highly severe scene), H4 (i.e., occasional, not easily noticed, and highly severe scene), and then H2 (i.e., frequent, not easily noticed, and highly severe scene). All these four scenes belonging to the category of being highly severe, were found with higher mean scores compared to the remaining four hazards which fell into the category of lower severity. It is indicated that respondents generally made reasonable judgements on the severity of the eight scenes in terms of their severity levels. The standard deviation analysis conveyed the information that the highest variation of perceptions were related to H3 and H8, both of which belonged to the category of higher frequency and lower severity. It can be inferred that construction employees tend to have a more varied view on more frequently occurring but lower severe accidents. Other hazards with more differed views among respondents (i.e., H2, H5, and H7) also fall into the category of either lower severity or higher frequency.

The Cronbach's alpha analysis was performed to test the internal consistency of the whole survey population's responses to the eight scenes. Table 3 summarizes the test results.

Table 3. Internal consistency analysis of the overall survey sample's perceptions towards the eight safety scenes (Overall Cronbach's Alpha = *0.8977*)

Hazards	H1	H2	H3	H4	H5	H6	H7	H8
Item-total Correlation	0.6515	0.8049	0.7424	0.7207	0.7829	0.5554	0.6895	0.5700
Cronbach's Alpha	0.8895	0.8726	0.8788	0.8819	0.8748	0.8953	0.8839	0.8990

The overall Cronbach's Alpha value at *0.8977* suggested a high internal consistency among the eight scenes, meaning that a survey participant who selected one Likert-scale score to one scene was likely to assign a similar score to another scene. The Item-total Correlation in Table 3 measures the correlation between the given scene and the remaining seven scenes. H2, with the correlation value over *0.800*, suggests that respondents' perceptions towards the scene in the categories of high severity, high occurrence, and not being easily noticed has a highly positive correlation with the overall perception of the remaining scenes. In contrast, respondents' perceptions towards H6 and H8 have the Item-total Correlation below *0.600*, indicating that respondents' perceptions towards these two hazards representing frequent and easily noticed scenes tend to differ from the remaining scenes. These two scenes receiving differed views from the survey sample can be found from their higher individual Cronbach's Alpha values compared to that of the remaining scenes listed in Table 3. H8 with its individual Cronbach's Alpha value (i.e., *0.8990*) higher than the overall value at *0.8977*, infers that it contradicts the overall consistency of the survey sample's perceptions towards these hazard/accident scenes.

Subgroup analysis between management personnel and workers

The whole survey population was divided into two main subgroups, namely the management personnel and workers. The former subgroup contained survey participants of either safety managers or other management personnel (e.g., project manager, assistant project manager, and foremen leading a certain trade of workers, etc.). The latter were workers working on certain trades defined in Fig.2. Using the two-sample *t*-test, these two types of site employees' perceptions towards each scene and the overall view are summarized in Table 4.

Table 4. Two-sample *t*-test results for subgroup analysis between management personnel and workers

Safety Hazards	Management personnel		Trade workers		Statistical comparison	
	Mean	Standard Deviation	Mean	Standard Deviation	*t* value	*p* value

H1	4.726	0.750	4.433	0.909	**2.09**	**0.039***
H2	4.330	1.030	3.920	1.340	**2.02**	**0.046***
H3	3.650	1.110	3.500	1.510	0.68	0.501
H4	4.450	1.030	4.250	1.020	1.20	0.232
H5	4.110	1.090	3.900	1.300	1.02	0.310
H6	4.580	1.020	4.450	1.030	0.76	0.447
H7	3.800	1.070	3.420	1.230	**1.99**	**0.049***
H8	3.120	1.340	2.870	1.460	1.07	0.287
Average	4.095	0.803	3.842	0.947	1.72	0.089

* A *p* value lower than 0.05 indicates the significant difference between management personnel and workers

Several significant differences of perceptions towards safety scenes between management personnel and workers can be found according to Table 4. Management personnel perceived more danger in the following three hazards in comparison to workers' views, including: 1) H1 representing the highly severe, occasional, and easily noticed scene; 2) the scene falling into the category of high severity, high frequency, and not being easily noticed; and 3) the scene which is lower in severity but more easily noticed and occasionally occurring. The higher degree of danger perceived by management personnel than workers can be explained by the job nature. According to Feng et al. (2017), management personnel usually have a higher education level and have received more systematic safety training which leads to a higher sense of safety accountability. Due to the job nature and duties, management personnel tend to focus on finishing the construction project with zero accident, while workers are more likely to risk by finishing their work ahead of schedule (Feng et al., 2017).

Subgroup analysis of survey participants among different trades or duties

The management personnel and workers were then further divided according to management duties and work trades according to Fig.2. Based on ANOVA results, the subgroup analysis is displayed in Table 5.

Table 5. Subgroup analysis of survey samples divided by job duties or trades

Trades or job duties	H1	H2	H3	H4	H5	H6	H7	H8	Avera-ge

Safety managem-ent personnel	Mean	4.929	4.455	3.545	5.000	4.364	4.818	3.455	2.636	4.159
	Standard Deviation	0.267	0.934	1.293	0.000	0.924	0.603	1.368	1.286	0.657
Other managem-ent personnel	Mean	4.691	4.310	3.667	4.381	4.071	4.548	3.845	3.179	4.086
	Standard Deviation	0.791	1.041	1.090	1.074	1.106	1.057	1.024	1.346	0.824
Student intern	Mean	4.667	4.500	4.167	5.000	5.000	5.000	4.333	3.667	4.542
	Standard Deviation	0.516	1.225	1.329	0.000	0.000	0.000	0.816	1.633	0.600
Carpente-r	Mean	4.571	3.571	3.286	3.857	3.286	4.143	2.571	2.714	3.500
	Standard Deviation	0.535	0.976	1.704	1.215	1.496	1.464	0.976	1.496	0.820
Scaffold-ing workers	Mean	4.000	4.000	3.667	4.333	4.333	3.330	4.000	4.667	4.042
	Standard Deviation	1.000	1.000	1.155	1.155	1.155	2.080	1.000	0.577	1.003
Concrete workers	Mean	4.500	4.000	3.500	4.100	3.750	4.550	3.150	2.850	3.800
	Standard Deviation	1.000	1.338	1.504	0.852	1.293	0.686	1.137	1.309	0.820
Electrical workers	Mean	4.000	3.154	3.000	4.000	3.462	4.231	3.538	2.077	3.433
	Standard Deviation	1.155	1.772	1.871	1.291	1.391	1.301	1.450	1.320	1.235
Plumbing workers	Mean	5.000	4.750	3.250	4.750	5.000	5.000	3.750	3.000	4.313
	Standard Deviation	0.000	0.500	0.957	0.500	0.000	0.000	1.258	1.633	0.415
Steel workers	Mean	4.571	4.429	4.143	4.571	4.000	4.571	3.571	3.000	4.107
	Standard Deviation	0.787	0.787	1.215	1.134	1.291	0.787	1.272	1.528	0.897
F value		1.70	**2.07**	0.79	1.55	1.98	1.17	**2.03**	1.84	1.70
p value		0.103	**0.042***	0.610	0.145	0.053	0.321	**0.046***	0.074	0.103

*: A *p* value lower than 0.05 indicates significant differences among subgroups towards the given scene

Two significant differences related to H2 and H7 can be found according to Table 5. Site employees among the nine subgroups had varied views on the scene of falling from uncovered openings which belongs to the category of high severity, high frequency, and not being easily noticed. Seven out of the nine subgroups all perceived H2 a highly dangerous scene, with the average score above *4.000*, except carpenters and electrical workers. Management personnel, who might have a more comprehensive coverage of safety knowledge in terms of different types of hazards/accidents, also believed that H2 was highly dangerous.

These nine subgroups also had varied views on H7 (i.e., falling from unstable ladder), which is generally considered lower severity, lower occurrence, and being easily noticed. The majority of subgroups also considered it less dangerous, with their average Likert-score between *3.000* and *4.000*, or even below *3.000* among carpenters. It could be assumed that carpenters generally had a higher chance of working with ladders and feel more comfortable with them at work. Therefore, carpenters tended to be more likely to underestimate the risk of working with ladders. On the other hand, student interns had a much more serious view on H7, with the average score at *4.333*. Student interns' overestimation of risks of working with ladders could be due to the fact that they did not have much site experience compared to the professionals who have been working for years. As inexperienced student interns, they might have received more school education emphasizing the importance of site safety and hence tending to pre-assume that most hazards/accidents were very serious. Furthermore, it can be found from Table 5 that student interns had the highest average Likert-scale score assigned to the eight scenes, inferring that they were prone to consider most hazards with a higher degree of severity. In contrast, it was analyzed by Han et al. (2017) that workers tended to be used to the site hazard after being exposed to more site accidents and gaining more experience, and as result, they are prone to underestimate the severity of hazards.

The effect of experience levels in safety perceptions

Following the finding that student interns had more serious concerns over site safety hazard/accident scenes in the previous section, the effect of experience levels in employees' perceptions towards hazards/accidents were further studied. The whole sample was divided into categories according to respondents' years of construction experience (see Fig.2). The subgroup analysis is summarized in Table 6 based on the ANOVA method.

Table 6. Subgroup analysis of survey samples divided according to site experience

Years of experience	H1	H2	H3	H4	H5	H6	H7	H8	Avera-ge

Below five years	Mean	4.738	4.279	3.754	4.459	4.164	4.623	3.869	3.311	4.150
	Standard Deviation	0.630	0.985	1.059	1.010	1.019	0.897	0.922	1.272	0.693
6-10 years	Mean	4.667	4.148	3.370	4.333	3.815	4.556	3.296	2.370	3.819
	Standard Deviation	0.734	1.231	1.275	0.920	1.241	1.050	1.353	1.245	0.838
11-15 years	Mean	4.440	3.800	3.080	4.080	3.760	4.080	3.240	2.400	3.610
	Standard Deviation	0.917	1.384	1.470	1.222	1.332	1.498	1.300	1.472	1.030
16-20 years	Mean	4.727	4.727	4.000	4.636	4.182	4.909	3.818	3.364	4.295
	Standard Deviation	0.647	0.647	1.265	0.674	1.328	0.302	1.250	1.362	0.793
21-25 years	Mean	4.143	3.714	3.571	4.286	3.714	4.287	3.571	2.929	3.777
	Standard Deviation	1.406	1.590	1.604	1.326	1.383	1.139	1.158	1.492	1.190
Above 25 years	Mean	4.647	4.353	3.882	4.471	4.412	4.765	4.000	3.765	4.287
	Standard Deviation	0.862	1.115	1.317	0.874	1.004	0.437	1.000	1.200	0.775
F value		1.50	1.64	1.59	0.69	1.21	1.76	2.06	**4.15**	**2.54**
p value		0.192	0.153	0.166	0.632	0.306	0.124	0.074	**0.001***	**0.031***

*: A *p* value lower than 0.05 indicates significant differences among subgroups towards the given scene

Table 6 suggests that subgroups from different experience levels had significantly different views on H8 (i.e., struck-by an object). H8 was considered the hazard with the lowest severity by the survey population according to Fig.3, especially by subgroups with construction experience from *6* to *15* years and *21* to *25* years. The average Likert-scale scores of the eight scenes were also found with significant variations among the six subgroups. It is indicated from Table 6 that newer employees with less than five years' experience and their peers with more than 25 years' experience tended to be more cautious on safety hazard/accident scenes, with both average Likert-scale scores over *4.000*. In contrast, those in their mid-career (i.e., with site experience between *6* and *15* years) were more likely to be risk takers by underestimating the severity of hazard/accident scenes. Employees from the various subgroups (i.e., site experience less than five years, between *6* and *15* years, between *16* and *20* years and over 25 years) all had lower standard deviations, indicating that they tended to have higher consistency of perceiving safety hazards. Employees with experience between *21* and *25* years had the highest variation of perceptions of the scenes, i.e. according to the standard deviation value of *1.190*. Based on the perception variations among these six subgroups, they can be further reduced into three main categories, namely early career construction employees with less than five years of experience, mid-career professionals with site experience between 6 and 15 years, and senior professionals with more than 16 years' experience. The mean values and standard deviations of Likert-scale-based average perceptions towards all the given scenes are displayed in Fig.4.

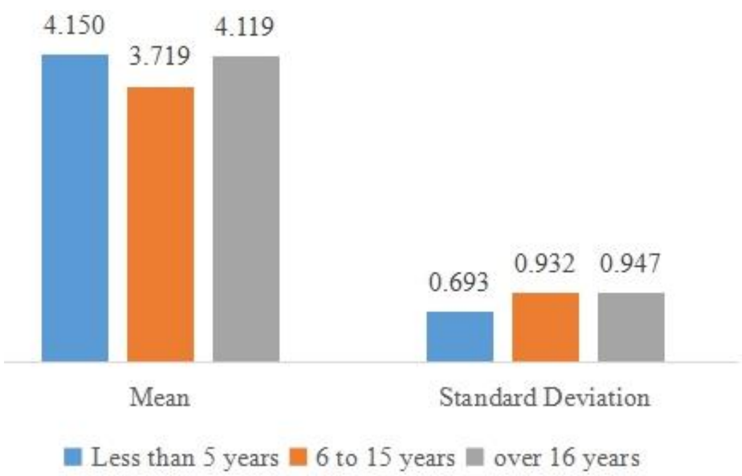


Fig.4. Comparison of average perceptions among three redefined subgroups

The ANOVA test was also performed to analyze the overall perceptions towards the eight scenes among the three different subgroups shown in Fig.4. All lower standard deviations below *1.000* indicate that survey participants generally held somewhat consistent perceptions within their own subgroups. With the F value at *4.200* and the corresponding p value at *0.017*, it is inferred that there were significantly different overall perceptions towards the eight scenes among the three redefined subgroups. Early career professionals had similar views with their senior peers. Both subgroups had significantly more serious views on the given scenes compared to the mid-career professionals. It can be further assumed that though early career employees had consistent perceptions with their senior peers, the rationale behind that could be different. The former subgroup, due to their less site experience, tended to be more careful of their safety behavior aiming to either prevent injuries or to gain incentives of working safely. The latter group, with more years spent in the industry, were likely to have experienced or witnessed more accidents/incidents, prone to behave more mature, and less likely to take risks to complete job duties as they might think that there were not many years left in their career (i.e. being relatively closer to retirement). Therefore, safety is more important to them compared to rushing to complete work in a more risky way. In comparison, mid-career professionals, with years of site experience but still had more professional time left compared to their senior peers, tended to underestimate risks of hazards or accidents. They might be more ambitious in being more productive and were hence more likely to take risks in order to complete site jobs.

Discussions

Based on the theory of psychometric paradigm and the site questionnaire survey-related research method, construction site employees' perceptions towards eight pre-defined hazard/accident scenes were studied in this research. Guided by Slovic (1992), researchers believed that construction employees' opinions on certain safety scenes were related to their own psychological, social, and cultural factors. In this study, hypotheses were established regarding whether individuals' perceptions were affected by their demographic features in terms of position (i.e., management or workers), job duties or trades, and experience levels. Eight different types of safety hazard/accident scenes were prepared for the site survey to construction employees. These eight scenes belonged to different combinations of safety categories according to their severity, occurrence, and ease of being noticed. Using safety accident data summarized from Division of Safety Supervision (2017) in China and the feedback from the pilot site study, categories of these eight scenes were determined. For instance, falling from working at height was determined as the scene with higher occurrence compared to pit collapse.

The overall sample analysis revealed that survey respondents generally had reasonable judgement on the different severity levels between highly dangerous scenes (e.g., loss of balance and falling) and lower severe scenes (e.g., hand injury due to being struck). Generally, safety hazards/accidents with lower occurrence would be perceived with a higher degree of severity by site employees compared to these with higher occurrence. The higher occurrence and lower severity of a safety hazard/accident would lead to more varied views among construction employees. In contrast, scenes corresponding to hazards/accidents with low occurrence but high severity would more easily arouse the concern of construction employees. It is inferred that the nature of a safety scene in terms of occurrence, would affect an individual's subjective judgement of its severity. Individuals' perceptions towards a certain scene would be more consistent when the accident is less frequently occurring, especially when it is also highly severe. The internal consistency analysis of the eight scenes demonstrated that the overall perceptions of individuals were highly correlated to the perception towards the scene representing high severity, high occurrence, but not being easy to detect. It is also worth noticing that individuals tended to have different views on frequently occurring and easily noticed hazards, compared to how they perceived the overall site safety hazards.

The subgroup analysis suggested that compared to workers, management personnel tended to perceive a few hazard/accident scenes with higher severities. That could be explained by the more education and more comprehensive safety training received by management personnel, who may also have a higher sense of safety accountability. By further dividing the whole survey sample into totally nine subgroups according to their job duties or work trades, the subgroup analysis revealed that trades or duties could affect employees' perceptions towards certain site safety hazard/accident scenes. For example, carpenters and electrical workers perceived falling from uncovered floor holes much less dangerous compared to other trades (e.g., plumbing). Student interns, with more college education but less site experience, tended to consider higher severities of these scenes (e.g., falling from unstable ladders). In contrast, full-time professionals, after experiencing more site accidents and gaining more practice, were more likely to underestimate the severity of the same hazard/accident scene.

This study also divided the whole survey sample into subgroups based on employees' levels of experience measured by number of years spent in construction. Initially the whole sample was categorized into six different subgroups. Following the initial sub-sample analysis using ANOVA, three subgroups (i.e., employees in their early career and mid-career, as well as senior employees) were re-defined. Mid-career construction employees (i.e., with site experience between *6* and *15* years), were more likely to underestimate the severities of safety hazards/accidents compared to their early career and senior peers. This could be due to the characteristics of mid-career professionals. Being more experienced in site jobs compared to their entry-level starters and being more ambitious compared to their senior peers, mid-career employees tended to be more over-optimistic of completing jobs without being injured by perceiving safety hazards/accidents with lower severity levels. As perceptions have a direct effect in human behaviors (Dijksterhuis and Bargh, 2001), mid-career professionals' underestimation of safety hazard/accident scenes could lead to unsafe behaviors. Therefore, it is suggested that safety orientation, training, and education should not only focus on entry-level or early career employees, but also to employees in their mid-career phase. Effective approaches in reinforcing the safety awareness and accountability of mid-career employees can be further studied in the future, such as using holistic approach incorporating case studies of safety accidents belonging to the category of high severity and low occurrence, design for safety in the preconstruction stage (Weinstein et al., 2005), and adopting digital technologies for automated construction safety checking (Lu et al., 2015), etc.

Conclusion

Incorporating the theory of psychometric paradigm, this research aimed to evaluate construction site employees' safety perceptions of eight designed hazard/accident scenes. Through the site survey followed by multiple statistical analysis methods in this research, several findings and corresponding recommendations guiding future research are provided below:

- construction employees had more varied views on hazard/accident scenes with higher occurrence and lower severity, and their opinions of the scenes with lower occurrence but higher severity tended to be more consistent. It was indicated that the occurrence of a hazard/accident scene would affect employees' perceptions of the given hazard/accident. Furthermore, it was suggested that a scene with low occurrence, high severity, and not being easily noticed could be more effective in being used in safety training and education;
- scenes easily noticed and more frequently occurring were more likely to be perceived differently by construction employees as they did with other types of scenes. Evaluation of employees' safety perception should also consider the nature of the hazard or accident;

- student interns tended to view safety hazards/accidents with higher severity. After entering the job market and gaining more experience in construction safety, they may become used to witnessing and handling site safety issues. As a result, they were more likely to underestimate the dangers of safety hazards. Future research could target tracking the career path of entry-level construction employees to study how their safety attitudes, safety perceptions, and safety behaviors change as they develop professionally. Corresponding strategies addressing the continuous safety training and education following employees' career path can be proposed;
- safety education and training should consider subgroup differences between management personnel and workers, as well as workers from different trades. It is suggested that while safety policies should be consistently implemented to all site employees, demographic or subgroup factors should also be addressed, especially to those subgroups that tend to underestimate risks or severities of safety hazards.
- the issue regarding the safety perceptions of mid-career site employees was also addressed in this study. As mid-career professionals might underestimate the severity of safety hazards (possibly leading to unsafe behaviors), it is recommended that safety awareness and safety education be reinforced to employees in their mid-careers.

This research contributes to the existing knowledge of human factors in construction safety by studying the effects of demographic factors (i.e., job positions, duties or trades, and experience levels) in the safety perceptions of site hazard/accident scenes with different levels of severity, occurrence, and ease of noticing. Though the site investigation conducted in China, the findings could be applied to a wider context; across the regions or countries. Future work will continue exploring more demographic factors in safety management, such as employees' educational background, gender, and age, etc. Further work in the field of construction safety management, as suggested, can focus on exploring effective safety training methods targeting non-early-career construction employees, especially those in their mid-career stage.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request.

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